Classification of power system stability

Power system stability

The stability of an interconnected power system means is the ability of the power system is to return or regain to normal or stable operating condition after having been subjected to some form of disturbance

Classification of power system stability

Rotor angle stability

Rotor angle stability is the ability of interconnected synchronous machines of a power system to remain in synchronism.

Steady state stability

Steady state stability is defined as the ability of the power system to bring it to a stable condition or remain in synchronism after a small disturbance. EE 2351 Power system analysis.

Steady state stability limit

The steady sate stability limit is the maximum power that can be transferred by a machine to receiving system without loss of synchronism

Transient stability

Transient stability is defined as the ability of the power system to bring it to a stable condition or remain in synchronism after a large disturbance.

Transient stability limit

The transient stability limit is the maximum power that can be transferred by a machine to a fault or a receiving system during a transient state without loss of synchronism. Transient stability limit is always less than steady state stability limit

Dynamic stability

It is the ability of a power system to remain in synchronism after the initial swing (transient stability period) until the system has settled down to the new steady state equilibrium condition

Voltage stability

It is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance.

Rotor Angle Stability:

Rotor angle stability is the ability of the interconnected synchronous machines running in the power system to remain in the state of synchronism. Two synchronous generators running parallel and delivering active power to the load depends on the rotor angle of the generator (load sharing between alternators depends on the rotor angle).During normal operation of the generator, rotor magnetic field and stator magnetic field rotates with the same speed, however there will be an angular separation between the rotor magnetic field and stator magnetic field which depends on the electrical torque (power) output of the generator.

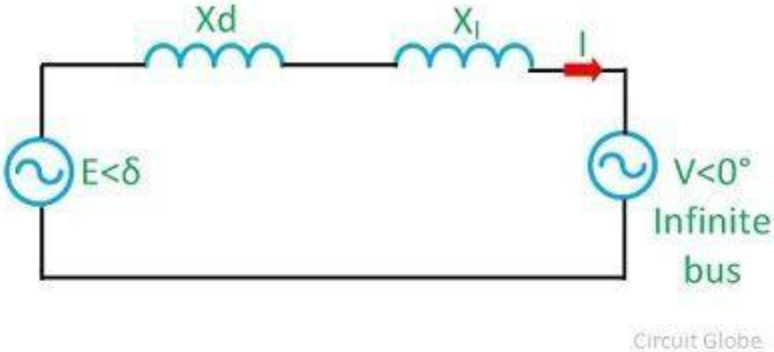
An increase in the prime mover speed (turbine speed) will result in the advancement of the rotor angle to a new postion realtive to the rotating magnetic field of the stator. On the other hand reduction in the mechanical torque will result in the fall back of the rotor angle relative to the stator field.

In equilibrium condition there will be equilibrium between the input mechanical torque and output electrical torque of each machine (generator) in the power system and speed of the machines will remain same. If the equilibrium is upset which results in the acceleration or deceleration of rotors of the machines.

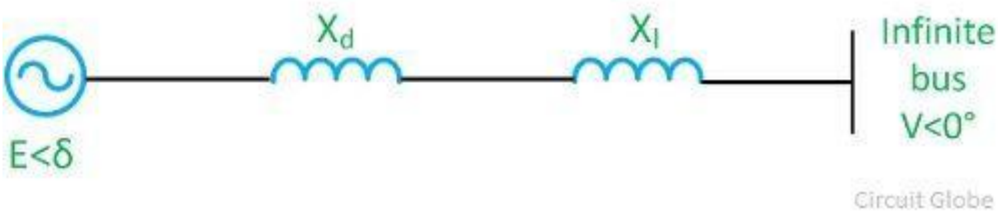
If one of the inter connected generator moves faster temporarily with respect to the other machine. rotor angle of the machine will advance with respect to slow machine. This results in the load deliver by faster generator increases and load delivered by slow machine decreases. This tends to reduce the speed difference between the two generators and also the angular separation between the slow generator and fast generator. Beyond certain point the increase in the angular separation will result in decrease of power transfer by the fast machine. This increases the angular separation further and also may lead to instability and synchronous generators fall out of synchronism.

Power-Angle Curve

Consider a synchronous machine connected to an infinite bus through a transmission line of reactance X_l shown in a figure below. Let us assume that the resistance and capacitance are neglected.



Equivalent diagram of synchronous machine connected to an infinite bus through a transmission line of series reactance X_l is shown below:



Let, V = V<0^0 – voltage of infinite bus, E = E<δ – voltage behind the direct axis synchronous reactance of the machine, X_d = synchronous / transient resistance of the machine. The complex power delivered by the generator to the system is

S = VI

$$S = V\left[\frac{E < \delta - V < 0^0}{j(X_d + X_l)}\right]$$

Let, $X_d + X_l = X$

$$S = V\left[\frac{E < \delta}{X < 90^0} + j\frac{V}{X}\right]$$

$$S = \frac{EV}{X} < (90^0 - \delta) - j\frac{V^2}{X}$$

$$S = V\left[\frac{EV}{X} sin\delta + j\frac{EV}{X} cos\delta - j\frac{V^2}{X}\right]$$

$$P_e + jQ_e = \frac{EV}{X} sin\delta + j\left(\frac{EV}{X} cos\delta - \frac{V^2}{X}\right)$$

Active power transferred to the system

$$P_e = \frac{EV}{X} sin\delta$$

The reactive power transferred to the system

$$Q_e = \frac{EV}{X} cos\delta - \frac{V^2}{X}$$

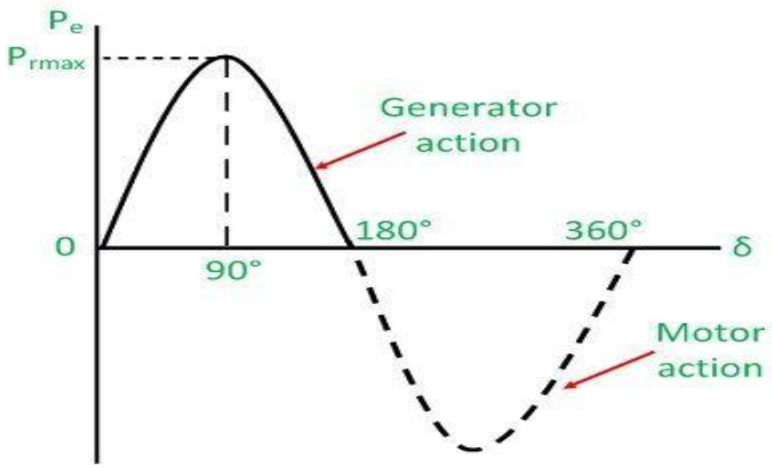
The maximum steady-state power transfers occur when δ = 0

$$P_e = \frac{EV}{X} sin90^0$$

$$(\sin 90^0 = 1)$$

$$P = \frac{EV}{X} \quad P_e = P_{emax} sin\delta$$

The graphical representation of P_e and the load angle δ is called the power angle curve. It is widely used in power system stability studies. The power angle curve is shown below



Power-angle diagram

Maximum power is transferred when δ = 90^0. As the value of load angle δ is above 90, P_e decrease and becomes zero at δ = 180^0. Above 180^0, Pe becomes negative, which show that the direction of power flow is reversed, and the power is supplied from infinite bus to the generator. The value of P_e is often called pull out power. It is also called the steady-state limit.

The total reactance between two voltage sources E and X is called the transfer reactance. The maximum power limit is inversely proportion to the transfer reactance.